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DEVELOPMENTAL LEVEL AND CONCEPT-LEARNING--A REPLICATION AND EXTENSION.

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TO VERIFY A PREVIOUSLY OBSERVED DEVELOPMENTAL INVERSION IN PROBLEM-SOLVING ABILITY AND TO EXPLORE PROBLEM-SOLVING STRATEGIES, RESEARCHERS GAVE A SET OF SEQUENTIAL-PATTERN RECOGNITION TESTS TO 316 CHILDREN, REPRESENTING NURSERY SCHOOL THROUGH SIXTH GRADE. EACH TEST CONSISTED OF FINDING TOKENS PLACED BEHIND 5 DOORS IN A PREDETERMINED PATTERN. THE CHILDREN WERE ALLOWED 50 TRIALS TO DISCOVER THE PATTERN. THE PERCENTAGE OF CHILDREN LEARNING EACH PATTERN SHOWS AN INCREASE FROM GRADE LEVEL TO GRADE LEVEL, EXCEPT FOR AN INVERSION AT GRADE 4. THIS INVERSION, WHICH WAS NOTED IN EARLIER WORK AND HAS BEEN SEEN BY SOME OTHER EXPERIMENTERS, MAY BE DUE TO INCOMPATIBLE RATES OF DEVELOPMENT OF INFORMATION-PROCESSING AND HYPOTHESIS-GENERATING ABILITIES USED IN PROBLEM SOLVING. THE STRATEGIES WHICH THE CHILDREN WERE USING WERE INFERRED FROM THE SEQUENCES OF THEIR CHOICES. YOUNG CHILDREN TENDED TO LOOK FOR THE PREVIOUS PATTERN IN A NEW TEST. AT ABOUT THE FIRST GRADE LEVEL THEY BEGIN TO ASSUME IT WILL BE DIFFERENT. IN GENERAL, YOUNGER CHILDREN TENDED TO USE SEQUENTIAL SEARCH PATTERNS. RANDOM SEARCHING APPEARS TO BE A LATER DEVELOPMENT. THE PATTERN 1, 3, 5 WAS EASIER TO IDENTIFY THAN THE PATTERN 3, 3, 5, BECAUSE THE CHILDREN SHOWED A PREFERENCE FOR HYPOTHESES LIKE 3, 3, 5, 5 OR 3, 5, 3, 5 AND WERE VERY RELUCTANT TO ABONDON THEM. FURTHER, WHEN THEY DID ABANDON THEM, THEY TENDED TO BEGIN SEARCHING RANDOMLY RATHER THAN TO MODIFY THE HYPOTHESIS. (DR)

DEVELOPMENTAL LEVEL AND CONCEPT-LEARNING: A REPLICATION AND EXTENSION

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Developmental Level and Concept-Learning:

A Replication and Extension[1, 2]

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Bruner, Wallach, and Galanter have noted that "...learning and problem-solving may be more profitably viewed as identification of temporally or spatially extended patterns" (1959. p.209). A number of investigators (Bruner, Wallach, & Gallanter, 1959; Galanter & Smith, 1958; Goodnow & Pettigrew, 1955, 1956; Simon & Kotovsky, 1963) have studied the recognition of sequential patterns by adult human subjects, and the conclusions have generally been that in learning to detect such patterns, subjects separate masking stimuli from relevant stimuli and then "learning is a matter of immediate recognition, provided the pattern can be handled in immediate memory-span" (Bruner et al., 1959. p. 208).

A survey of the literature has revealed only three systematic developmental studies of sequential-pattern identification (Friedman, 1965; Goldman & Denny, 1963; Hodges, 1954). The last two studies used the double-alternation problem (AABBAABB...), and, though using different criteria for successful performance, found a relatively simple direct relationship between success at the task and age (only male subjects were used). Both found a direct relationship between success and intelligence level, though not as close as the relationship

with age. (The classic studies by Gellerman [1931] and Hunter & Bartlett [1948] on the double-alternation problem present difficulties of interpretation due to the fact that extremely small sample sizes were tested: 38 children ranging in age from three- to thirteen-years in the former study, and 31 children ranging from two-years to six-years nine-months in the latter. However, both experimenters found that performance, measured by number of trials to criterion, improved at each successive age level.) Friedman (1965), using four sequential patterns, replicated the direct relationship between success and school grade with, however, an inversion at the fourth-grade level (third-graders showing performance superior to that of the fourth-graders). This finding had been reported previously by a number of investigators using other types of problems, e.g. Klugh, Colgan, & Ryton (1964), Torrance (1961), Yamamoto (1962). (It is interesting to note that in Gellerman's data [1931] a slight inversion does occur from ages nine to ten!) Friedman (1965) suggested that the fourth-graders had reached a transitional developmental level where the inexpert use of a newly developing problem-solving technique reduced intellectual efficiency. Similarly, Weir noted that the "...middle-aged child may be capable of complex hypotheses, but he is unable to make full use of the information available from his own responding. This...explanation would suggest...the 7- to 10-year-old is at a point in development where his ability to generate

complex hypotheses and employ complex search strategies is growing at a faster pace than his information-processing ability, which catches up only at a later age" (Weir, 1964, p. 481).

The present study is a replication and extension of one reported earlier (Friedman, 1965). It attempts to view this developmental inversion in the context of sequential-pattern identification and to explore the kinds of strategies and hypotheses with which the children at the various grade-levels attack the problems.

Method

Subjects

Two groups of nursery-school students (NSS) were used. The younger group (YNSS), consisting of eight males and nine females, had a mean age of 5-0 years, average deviation 1.8 months. The older group (ONSS), with nine males and eight females, had a mean age of 5-9 years, average deviation 2.8 months.

The elementary school students (ESS) were all from one Louisville public-school, and all children in each participating class were tested. Only the results of those children who had never repeated a grade (and thereby were in the correct age-grade placement) are reported in this study. The resulting population was: first-grade—25 male, 33 female; second-grade 22 male, 20 female; third-grade—23 male, 26 female; fourth-grade—24 male, 29 female; fifth-grade—20 male, 14 female;

sixth-grade--21 male, 25 female.

Two comments are appropriate at this point: (a) The NSS came from families of a higher socioeconomic level than the public-school students (approximately upper-middle class vs. lower-middle class); (b) Each teacher was asked to rate her class academically with respect to other classes of the same grade she had previously taught. The results are as follows: first-grade--both classes average; second-grade--both average; third-grade--one average, one superior; fourth-grade--two average, one superior; fifth-grade--both average; sixth-grade--two low, one superior. Thus, the results for the sixth-grade must be treated cautiously, since two classes are considered academically poor.

Apparatus

A three-sided box (open side facing the experimenter) having five doors was used. The front of the box was 18 inches high and 36 inches wide; the doors were 4 inches high and 3 inches wide and equally spaced across the width of the box front; they were hinged at the top. The sides of the box were extended back 12 inches so as to preclude the possibility of a subject observing the experimenter. The base of the box behind the doors was covered with green felt.

Procedure

The subject was instructed as follows: "You see this box has five doors, [pointing]. Each time you hear the word 'Go' you may open any one of the doors you want, but you may only

open one door each time you hear the word 'Go!' If you open the correct door, you'll find a plastic token like this [shown to the child] behind the door. If you do find a plastic token, reach in, take it out, and put it in this box [cardboard box provided the child]. Try to get as many tokens as you can; you'll have many chances to open the doors. Any questions? [Any questions were answered by paraphrasing the above instructions.] Then let's play the game."

The tokens were placed behind the doors in four different sequential orders: 2,2...; 4,2,4,2...; 1,3,5,1,3,5...; 3,3,5, 3,3,5...(the numbers refer to the doors; door 1 being the door to the subject's left). Fifty trials (a trial consisting of a single choice) were given for each sequence, and a token was kept behind the appropriate door until it was found by the subject, at which time a token was placed behind the next door in the sequence. The children collected the tokens in a box placed in front of them. A record was kept of the choices made by each subject, and, after each series of fifty trials, the child was asked to show where he had found the tokens. (All tokens were returned to the experimenter at the end of each four-sequence-session.) During the course of the study, it was found necessary to deviate from the set procedure in the following manner: the superior class of sixth-graders tended to become extremely restless soon after discovering any of the sequences, so, in order to keep them sufficiently motivated, not

all sequences were continued for the full fifty trials; rather they were discontinued after the criterion level had been reached; the NSS tended to lose interest in the task if they met with a great degree of failure, so they were not tested on 1,3,5 if they had failed to produce the 4,2 sequence. Those producing the 4,2 sequence were tested on both 1,3,5 and 3,3,5.

Scoring

For the sequences 2,2; 4,2; 1,3,5; 3,3,5; respectively, the success criteria (number of correct sequence-productions) over a series of fifty trials were: ≥ 18; ≥ 3; ≥ 3; ≥ 3. A sequence was considered correctly produced if for the last twenty-five trials the following criteria were met: ≥ 10; ≥ 2; ≥ 2; ≥ 2. The last two sequence protocols were also considered correct if the sequences were at any point correctly produced twice consecutively.

Any scoring system which requires, say, sixteen consecutive correct responses (as did Goldman & Denny, 1963) is likely to bias the results against the younger subjects who, though they may be responding at a level greater than chance, have not yet reached the arbitrary criterion. The rationale behind the present scoring system can be found in a previous study (Friedman, 1965).

Results

Table 1 shows that, except for the 2,2 sequence, the ONSS surpass the YNSS. For the 2,2 sequence, the younger group

performs substantially better. However, when we look at Table 2, we see that this difference is caused entirely by the performance of the female subjects (88.8% vs. 25.0%). It would

Insert Tables 1 & 2 about here

seem very likely that this result is due to some uncontrolled facit of the experimental conditions since these female ONSS far surpass the younger group on the 4,2 sequence. Further, all of the ONSS were able to correctly identify the appropriate door (on 2,2) when questioned after the initial fifty trials.

For the ESS, there is a continuous increase with grade in the percentage of successes, except for the expected inversion at the fourth-grade. The mean drop is greater for the female subjects, replicating findings by Torrance (1961) and Friedman (1965). A class-by-class comparison showed that the superior third-grade class surpassed the superior fourth-grade class on all four sequences.

Since, as has been noted, the results for the sixth-grade must be cautiously interpreted, Table 1 also includes the results of the one superior class at that grade-level (the large deviance in academic rating was confirmed by the fact that only at this grade-level was there seen any substantial inter-class variation in performance.

Table 3 shows the percentage children at each grade-level who immediately repeat their response to door 2 after their

Insert Table 3 about here

first reinforced trial on the 2,2 sequence. The slight variation across grade reflects little more than the varying sample sizes. These results severely limit generalization of the findings of Stevenson & Weir (1961) who reported substantial variations across age (younger subjects tending to immediately repeat the reinforced response), using a three-choice discrimination task. It seems likely that a complex interaction exists between, among other variables, number of alternatives and age. At any rate, the present results would appear to indicate that even the youngest subjects (five-year-olds) are performing at a level which cannot be completely encompassed by a S-R framework utilizing single-unit responses as a performance measure.

Table 4 gives some indication of the subjects' expectancies. After a subject successfully produces the 2,2 sequence,

Insert Table 4 about here

he most likely expects the task (i.e. the correct response) either to remain the same or change, (assuming he conceptualizes the problem in these terms) an indicant of his expectancy being his initial response on the immediately following series of trials. Thus, a subject who expects the task to remain the same would most likely choose door 2 as his initial response on the 4,2 sequence. We see from Table 4 that there is relatively little inter-grade variability in this expectancy, though the fifth- and sixth-graders seem to show a greater expectation

that the task will change. However, at all grades the subjects choose door 2 substantially above the chance level of 20%.

Discovering their expectation to be incorrect, and proceeding to correctly produce the 4,2 sequence, we may observe what percentage at each level modify their disconfirmed expectancy or set (that the previous response will remain correct). We see that the NSS continue to pursue the previously correct response at greater than the chance level (40%). The ESS data does not show any trend; there is a general tendency to shift set towards an expectation of "change." (So few of the younger children produced 1,3,5 correctly, that there were insufficient data with which to compute initial response on the last sequence.) It is interesting that the greatest shift in set occurs at the fourth-grade level.

Table 5 presents the mean trial at which criterion was reached for each sequence for all grade-levels (excluding those

Insert Table 5 about here

cells for which too few subjects, $N < 10$, were available). There are no trends or substantial differences across levels.

Discussion

There is a continuous increase with grade-level in the percentage of children who successfully produce the sequences, except for an inversion at the fourth-grade level. The (generally) continuous increase in percentage replicates findings

of: Friedman (1965); Goldman & Denny (1963); and Hodges (1954). The inversion replicates the finding of Friedman (1965), but was not found in the other two studies, both using the double-alternation problem (the former study using a two-choice task, and the latter a five-choice task). In the present study, it was noted repeatedly on the 3,3,5 sequence that the children (especially the fourth-graders) would apparently "jump to the conclusion," that the sequence was 3,3,5,5 (or 3,5,3,5), thus, it may be that there exists some sort of pretask bias towards pattern-symmetry (it had been noted in the first study that many of the children seemed to begin the session expecting a simple two-door alternation pattern). It would follow from this analysis that a primary hypothesis in any hierarchy of hypotheses generated by fourth-graders would be one likely to result in the rapid solution of a double-alternation problem, thereby precluding the demonstration of any inversion.

Torrance (1961) reported the inversion using a variety of measures of creative thinking; the only test showing no inversion was one of "hypothesis-generation"--he found a continuous developmental increase in the ability to generate hypotheses. Using the same types of measures, this inversion was replicated by Yamamoto (1962).

Klugh et al. (1964), using a concept-formation task, reported the fourth-grade inversion; when they repeated the study (Klugh & Roehl, 1965) with <u>different instructions</u> (<u>indicating</u>

the existence of a "rule") and a correction procedure, the inversion did not appear (on their simplest problem, however, no significant differences were reported between the five- to six-year-olds and nine- to ten-year-olds).

What are the responsible antecedent factors for this inversion? Two processes, in the main, are necessary for the solution of any problem-sequence: information-processing and hypothesis-generation. If we assume that these processes develop at rates which are usually parallel but sometimes diverge, then it may be that one process accelerates or decelerates, for a time, at a greater rate than the other, resulting in inefficient problem-solving behavior; this has already been suggested by Weir (1964). Since Torrance (1961) found a continuous developmental rise in facility at hypothesis-generation, we may speculate that the inversion is caused by a transient levelling-off in rate of development of information-processing ability, which, though it undoubtedly may occur with individual subjects at almost any developmental level, appears to be especially prevalent at the fourth-grade level. Unfortunately, we have not been able to find any studies which have attempted to measure information-processing at these ages.

Strategy changes in successful pattern-identification with age can only be explored by analyzing individual protocols, but these strategies can only be *inferred* from the data. Table 4 presented an attempt to get at the shifts in set associated

with the different developmental levels, and it was noted that at all levels the majority of subjects successful at the initial sequence expected the task to remain unchanged. Then, of those who successfully produced the second sequence, the majority, except at the nursery school level, shifted their set towards an expectation of "change" on the third sequence. The ESS surpassed the NSS at this shift, but no substantial differences or trends were found within the ESS data. So the most we can say is that it is likely that a major shift in "set strategy" occurs at about the first-grade level. A similar finding was reported by Weber (1965).

Table 5 indicated no significant differences across developmental level in the number of trials to criterion. It seems, then, that there are no objective differences among the protocols of successful subjects across developmental levels (other than the gross one between NSS and ESS).

In order to ascertain whether the noncriterion protocols were qualitatively different at the various grades tested, a separate analysis was made of the protocols of unsuccessful subjects. Younger subjects had been seen to respond more often in patterns composed of responses to adjacent doors; they were more likely than the third- to sixth-graders to use the "search" pattern 1,2,3,4,5, or some variation such as 5,4,3,2,1. Thus a pattern composed of nonadjacent elements seemed empirically to be a more sophisticated search-technique, so an analysis was

made of the number of times any single response was followed by a response to a nonadjacent door. NSS data had to be excluded since the sample sizes were too small; $N<10$ for all but one cell.

The percentage of nonadjacent choices rises steadily from first- to third-grade, levels-off from third- to fifth-grade and then rises again (except for the 4,2 sequence which levels-off after the first-grade). The percentage of nonadjacent choices ranges from high to low in the following order: 1,3,5; 3,3,5; 2,2; 4,2. At the fifth- and sixth-grades 1,3,5 and 3,3,5 exchange positions. Thus, it appears that the unsuccessful subjects demonstrate a qualitative developmental change in strategies.

It can be seen, then, that of all the measures used, only overall percentage of successes differentiates performance of successful subjects among the various grade-levels. We have already quoted Bruner et al. (1959) to the effect that the learning of such patterns is a matter of immediate recognition, assuming the pattern can be retained in immediate memory span. In this study, the patterns 1,3,5 and 3,3,5 would seem to require the same memory span and yet the latter sequence proved to be much the more difficult of the two. According to the speculation of Bruner and his colleagues we should expect the difficulty, then, to lie in the area of "recognition." Gibson (1966) presents some interesting ideas relevant to this position;

he notes "Perhaps, as Lashley suggested, the brain resonates to whatever is invariant under transformation and becomes increasingly attuned to it with recurrence over time. If so, perception and learning could be accounted for without any assumption of memory considered as an accumulation of traces. The brain would be a self-tuning resonator, not a storehouse" (p.146). Perhaps sequences of the form 1,3,5 have a greater frequency of occurrence in the environment than do those of the form 3,3,5.

A common mistake was one which we might call "false-recognition." For example, after successfully producing the 4,2 sequence, many subjects then opened doors 1 and 3 (on the 1,3,5 sequence) and assumed the correct order was 1,3,1,3..., then, when their hypothesis was disconfirmed, they apparently discarded the partial-solution and began searching anew without transforming the already gathered information for use with a new or modified hypothesis. Similarly, many of the subjects assumed that the last sequence was 3,5,3,5... or 3,3,5,5..., and after disconfirmation (some subjects required repeated disconfirmations before they would abandon this hypothesis) began testing anew, opening doors 1,2, and 4, instead of simply modifying their hypothesis. Thus, it is not merely "recognition" (in the narrow sense of <u>initial</u> hypothesis-generation) which is necessary, but "modification of a disconfirmed hypothesis." The subject must be able to select from a repertoire of patterns and methods-of-transformation of these patterns.

The basic question, that of the origin of this repertoire of patterns and transformational rules, still remains. The results of the present study, showing no substantial qualitative developmental changes among successful subjects (within the age-range studied) other than the shift in expectancy at about the first-grade, seem to suggest the <u>discontinuous</u> acquisition of patterns and/or transformational rules. However, the analysis of the noncriterion protocols indicates, for at least one strategy, a <u>gradual</u> change across some grade-levels, and a levelling-off (assimilation?) across others. This increasing sophistication of search-technique contrasted with unsuccessful performance immediately suggests two possibilities: (a) some sort of absolute threshold on a quantitative continuum representing search strategy, however, this would not explain the fourth-grade inversion; (b) sophistication of strategy is a necessary but not sufficient factor for successful performance. In any case, the replication of the fourth-grade inversion clearly invites the speculation that the major processes contributing to skill at sequence-identification progress at different, and, not necessarily parallel rates.

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Footnotes

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Table 1

Percentage Children Producing Sequences

Grade-level	Sequence			
	2,2	4,2	1,3,5	3,3,5
YNSS	88.2	29.4	0.0	0.0
ONSS	58.8	52.9	5.8	5.8
First	67.2	41.4	8.6	6.9
Second	71.4	61.9	28.6	19.0
Third	93.9	83.7	61.2	44.9
Fourth	81.1	75.5	41.5	35.8
Fifth	94.1	85.3	67.6	52.9
Sixth	95.6	91.3	71.7	52.1
Sixth[a]	100	100	90.5	80.9

[a]Superior sixth-grade class.

Table 2

Percentage Males and Females Correctly Producing Sequences

Grade-level	Male				Female			
	Sequence				Sequence			
	2,2	4,2	1,3,5	3,3,5	2,2	4,2	1,3,5	3,3,5
YNSS	87.5	25.0	0.0	0.0	88.8	33.3	0.0	0.0
ONSS	88.8	50.0	0.0	0.0	25.0	62.5	12.5	12.5
First	68.0	44.0	4.0	4.0	63.6	39.3	12.1	9.1
Second	86.3	86.3	36.3	27.3	55.0	35.0	20.0	10.0
Third	91.3	86.9	56.5	43.5	96.1	80.7	65.4	46.1
Fourth	79.2	83.3	33.3	41.7	82.7	68.9	48.3	31.0
Fifth	90.0	85.0	75.0	65.0	100	85.7	57.1	35.7
Sixth	95.2	100	71.4	61.9	100	88.0	72.0	44.0

Table 3

Percentage Immediately Repeating First Reinforced Response on 2,2

	Percentage repeating response	
Developmental level	Present study	Stevenson & Weir (1961)[a]
3-year-olds	—	83
YNSS	5.8	—
5-year-olds	—	48
ONSS	5.8	—
First grade	3.4	—
Second grade	3.1	—
7-year-olds	—	28
Third grade	1.6	—
9-year-olds	—	25
Fourth grade	3.3	—
Fifth grade	5.6	—
Sixth grade	1.6	—

[a]Data was unreported; these percentages are derived from their Fig. 1 (p.3).

Table 4

Percentage Correctly Producing Sequence Who Then Use Same Response on First Trial of Following Sequence

Grade-level	Open 2 on 4,2[a]	Open 2 or 4 on 1,3,5[b]
YNSS	73.3	60.0
ONSS	80.0	50.0
First	71.0	25.0
Second	76.6	38.4
Third	71.7	29.2
Fourth	71.4	17.5
Fifth	50.0	27.6
Sixth	60.0	23.2

[a]Chance level is 20%.

[b]Chance level is 40%.

Table 5

Mean Trials to Criterion

Grade-level	Sequence			
	2,2	4,2	1,3,5	3,3,5
YNSS	32.0	a	a	a
ONSS	30.8	a	a	a
First	33.8	25.3	a	a
Second	33.5	26.4	30.2	a
Third	31.3	20.0	23.7	33.3
Fourth	31.3	25.0	27.5	38.9
Fifth	30.2	24.4	26.8	31.3
Sixth	30.1	20.5	23.6	29.3

[a] $N < 10$ subjects.